IMPRS LECTURE DAY: GQFT
24 NOV 2017

FINAL LECTURE SEE ALSO 16.10.2023

SO FAR:
ORIGINS OF HOLOGRAPHY + ITS BASICS (HELLER)
HOLOGRAPHY AND CFT (DAS)
HOLOGRAPHY, GRAVITY AND QUANTUM INFO (JEFFERSON)

TODAY:
HOLOGRAPHY AS A TOOL:

(CERTAIN) QFTs ⟶ (CERTAIN) DYNAMICAL SPACETIMES
EMERGENCE OF SPACETIME

ONE CAN ALSO DO THE OPPOSITE:

CHALLENGING QFT CALCULATION ⟵ SOLUTIONS OF EINSTEIN EQS. WITH $\Lambda < 0$ + MATTER
TOOL

(CONCEPTUALLY WELL-DEFINED AT THE MICRO LEVEL BUT HARD IN PRACTICE)

(NOT WELL-DEFINED BY ITSELF AT THE MICRO LEVEL BUT "EASY" WHEN JUST USING GRAVITY)

VAST LANDSCAPE OF DEVELOPMENTS

FOCUS HERE: NON-EQUILIBRIUM PHYSICS OF QUARK-GLUON PLASMA (QGP)

WHY: BECAUSE WE ACTIVELY PURSUE THIS DIRECTION HERE.

IDEA: BLACK HOLES REPRESENT EQUILIBRIUM PLASMA

$$S \sim \text{"CENTRAL CHARGE } C\text{"} \, T^{d-1}$$

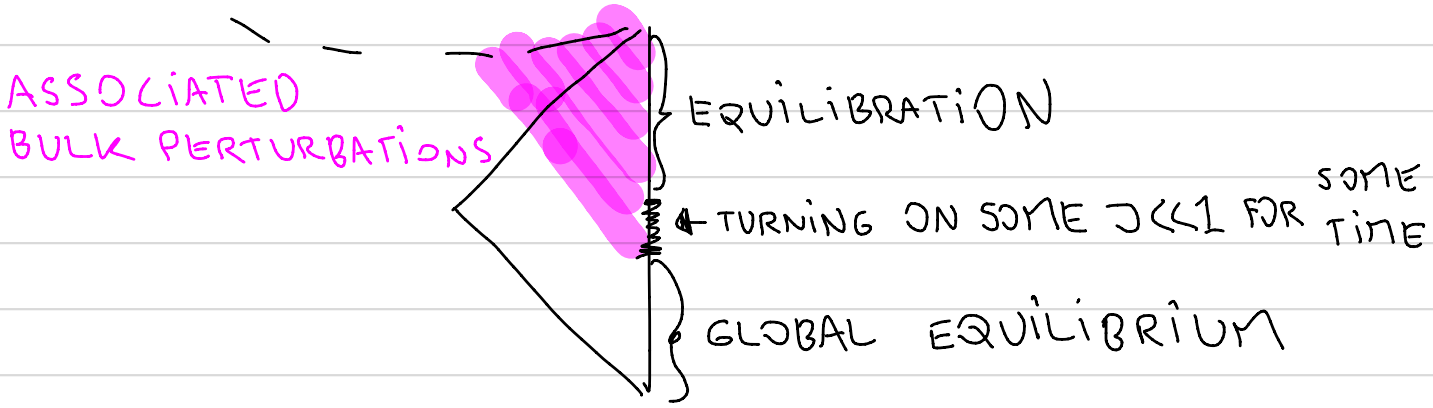
↑

FOR $d=3+1$ HOLOGRAPHIC $SU(N_c)$ YANG-MILLS THEORIES (E.G. $\mathcal{N}=4$ SYM), $C \sim N_c^2$. THIS MEANS SYSTEM HAS ACCESS TO GLUONIC DEGREES OF FREEDOM → DECONFINEMENT → "QGP" PHASE

* ONE CAN MAKE IT EVEN MORE PRECISE USING WILSON LOOPS → GOOGLE "HOLOGRAPHIC WILSON LOOPS" AND RELETED QUERIES

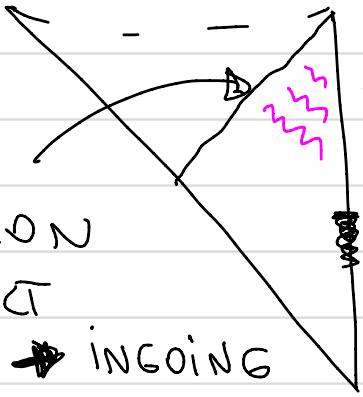
WHAT KIND OF SYSTEMS ARE THEY?

IMAGINE THE FOLLOWING EXPERIMENT



LET'S LOOK AT THE EQUILIBRATION PART

$\Psi = \chi(u)\, e^{-i\omega t + i\vec{k}\vec{x}}$ WITH $\chi(u) << 1$



BH HORIZON IS A PERFECT ABSORBER → INGOING BDRY CONDITIONS FOR Ψ

← DIRICHLET BDRY CONDITION FOR Ψ AT THE BDRY (SINCE $J=0$)

$+ \quad \Box_{BULK}\Psi + \ldots = 0 \quad +$

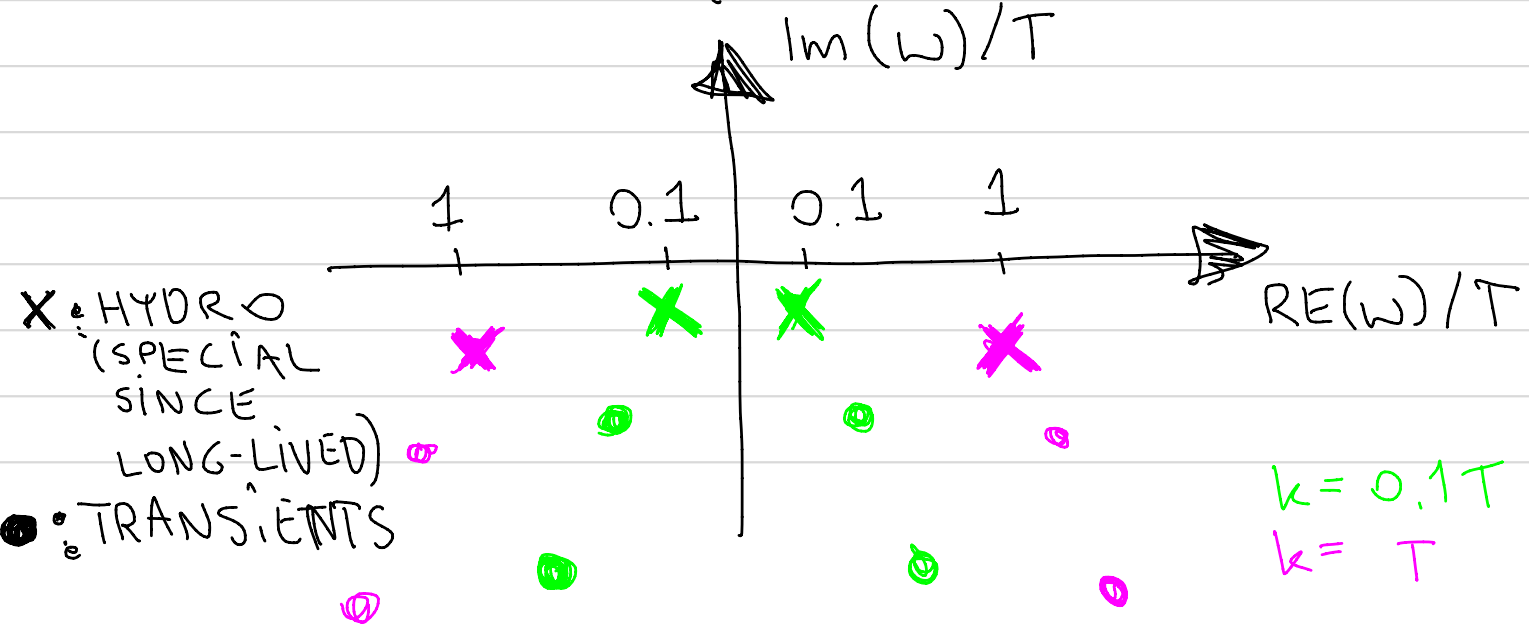
↓

NON-STANDARD EIGENVALUE PROBLEM FOR ω'S → QUASINORMAL MODES

↓

∞-MANY COMPLEX SOLUTIONS FOR $\omega(k)$ WITH $\mathrm{IM}(\omega) < 0$

FOR Ψ REPESENTING δg_{ab} WE SEE N THE FOLLOWING:



THE FACT THAT WE OBSERVED EQUILIBRATION IMPLIES PRESENCE OF INTERACTIONS IN AN UNDERLYING QFT. KEY QUESTION: WHAT IS THE INTERACTION STRENGTH?

$\mathrm{Im}(\omega)$ RESPONSIBLE FOR DISSIPATION
NO INTERACTIONS → JUST OSCILLATIONS FROM $\mathrm{Re}(\omega)$

SMALL INTERACTION STRENGTH → $\mathrm{Im}(\omega) \ll \mathrm{Re}(\omega)$ (QUASIPARTICLES)

HOLOGRAPHY → $\mathrm{Im}(\omega) = \mathcal{O}(\mathrm{Re}(\omega))$

INTERPRETATION: HOLOGRAPHIC (I.E. WITH 2-DERIVATIVE GRAVITY DUALS) QFTs ARE ALL STRONGLY INTERACTING

THIS CAN BE CONFIRMED / DERIVED USING STRING THEORY METHODS

WHERE DOES SIGNIFICANT INTEREST IN APPLICATIONS STEM FROM?
IT IS JUST PLAIN, HARD TO DO AB INITO CALCULATIONS IN STRONGLY COUPLED QFTs.

$\mathrm{Im}(\omega)$ FOR TRANSIENT → EQUILIBRATION RATES

HERE: SMALL k EXPANSION OF $\omega(k)$ → TRANSPORT PROPERTIES (E.G. $\eta/s = 1/(4\pi)$) FOR HYDRO

BOTH OF CRUCIAL INTEREST FOR QCD IN THE CONTEXT OF HEAVY ION COLLISIONS AT RHIC AND LHC.